Science Mission Directorate

Earth-Sun System Science: Potential Future Measurements/Missions

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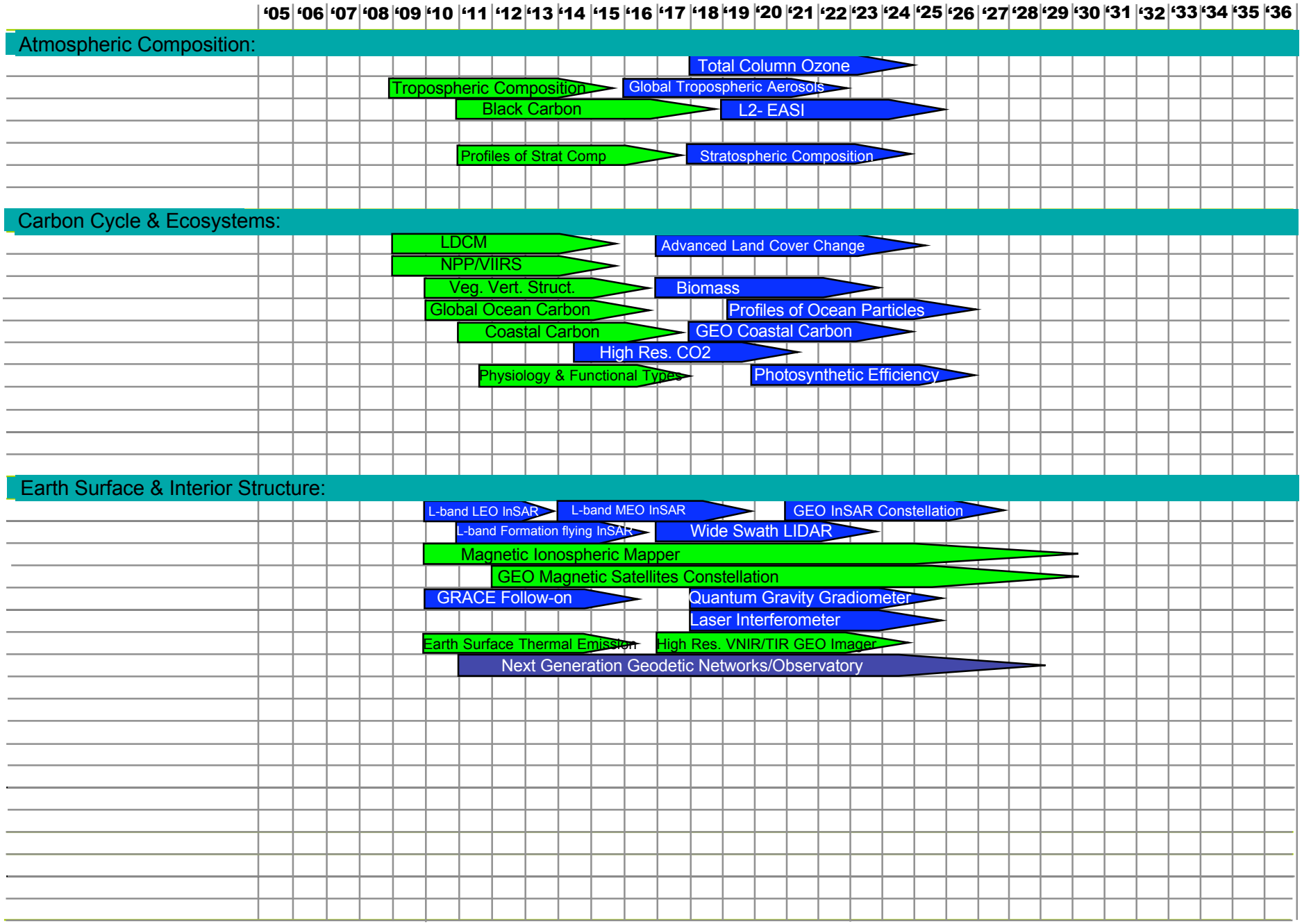
Introduction

- NASA organizes Earth-Sun System research into seven interdisciplinary science Focus areas
- Pursuing science questions can be addressed via remote sensing leads to potential approaches to acquiring observations from space
- Developed a discipline process to match science needs and technologies that coalesce around notional mission concepts
- Package contains
  - notional missions concepts with science objectives
  - measurement strategy
  - technology requirements
- Charts role up into time phase reflects only technology readiness and operating time - does not reflect science prioritization across focus area or make assumptions about budget availability

12/14/04

Earth Sun System (ESS) Science Measurements Roadmap



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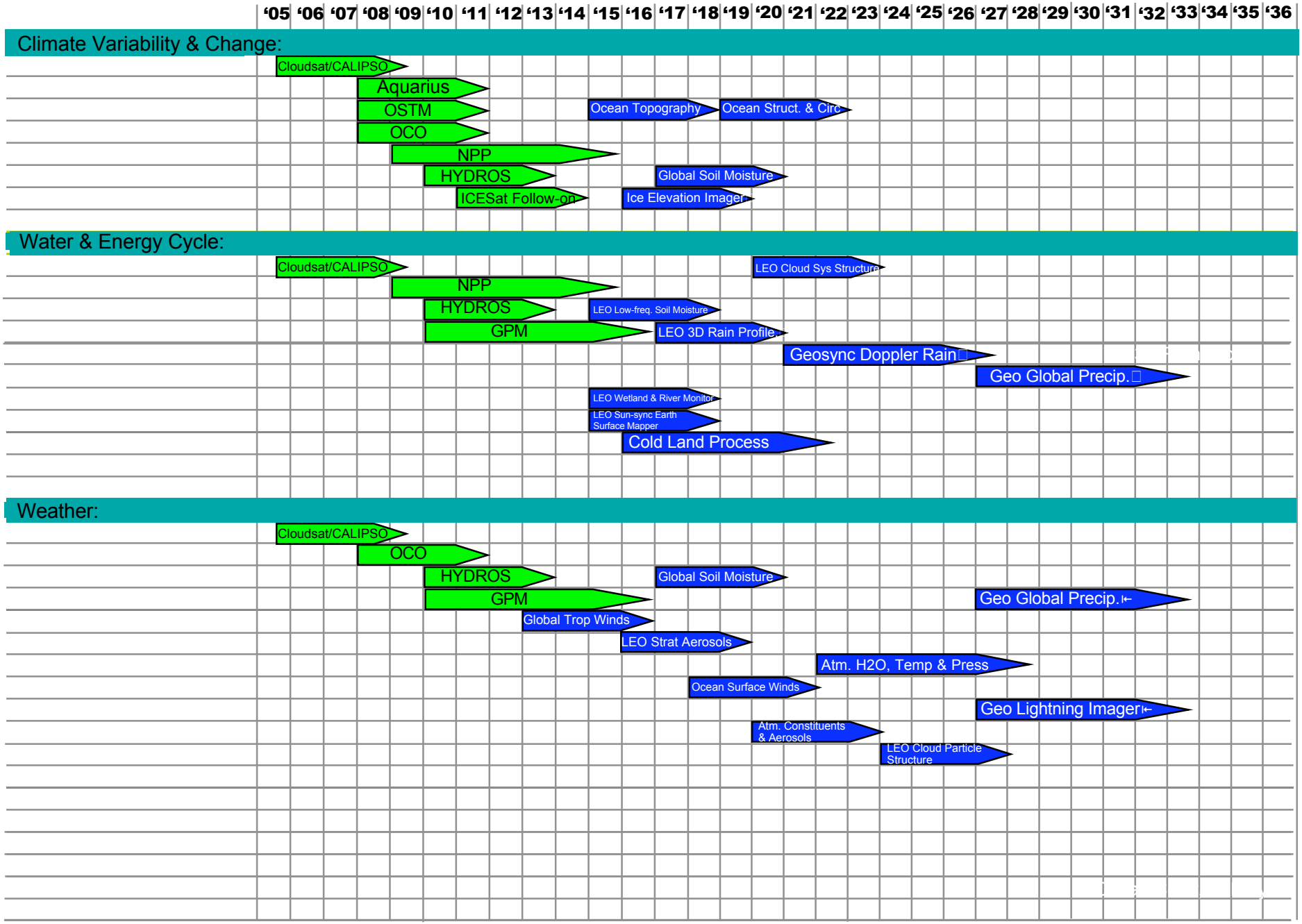
Earth Sun System (ESS) Science Measurements Roadmap



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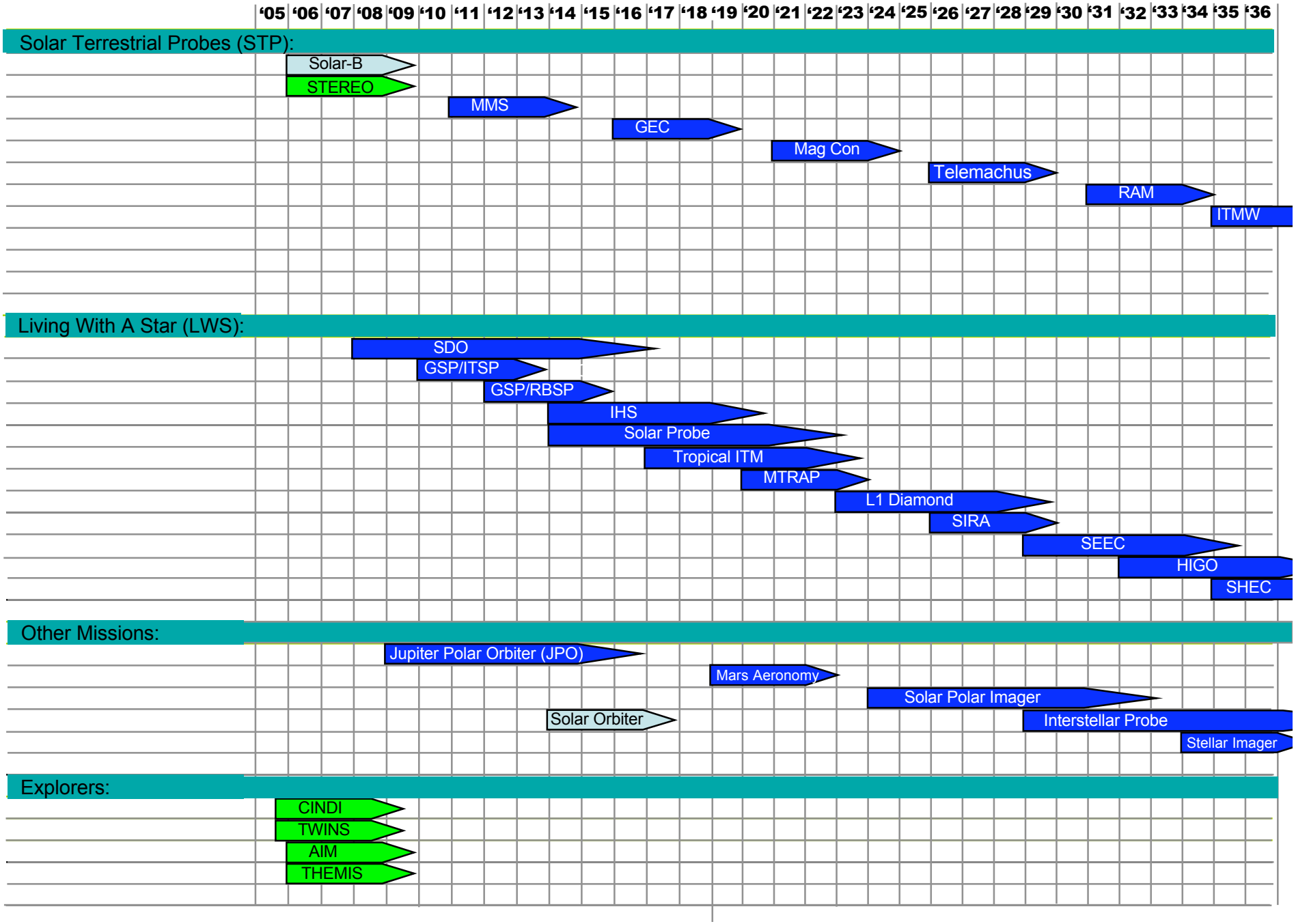
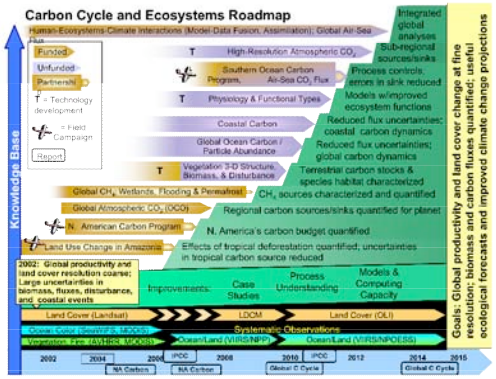
Earth Sun System (ESS) Science Measurements Roadmap

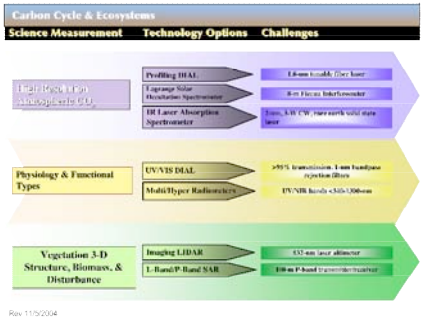


The Development Process

Starting with the **science** focus area **roadmap**…



… *science measurement challenges (science roadmap Ts) and technology requirements database information are used to identify technology options and key challenges…*

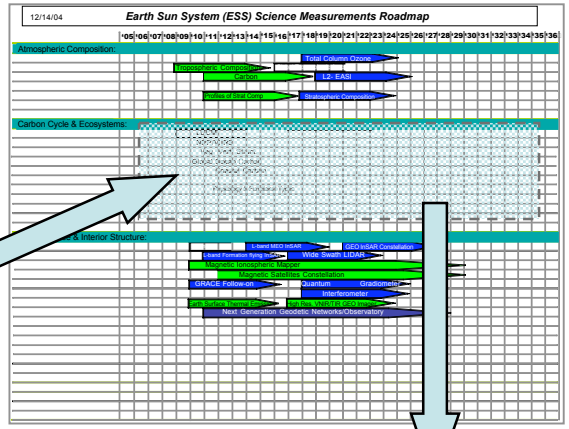


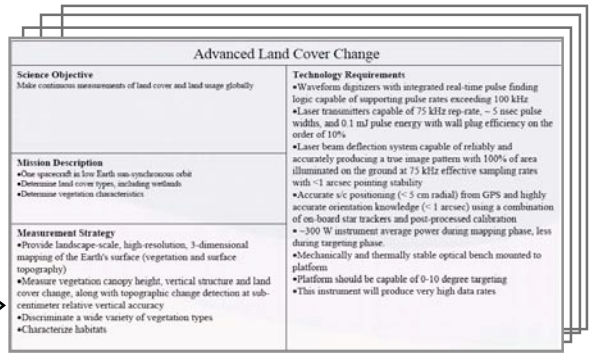
Technology requirements database (ESTIPS)

… *information on the science roadmap is used to create a* ***matrix of science objectives****, and possible measurement scenarios…*

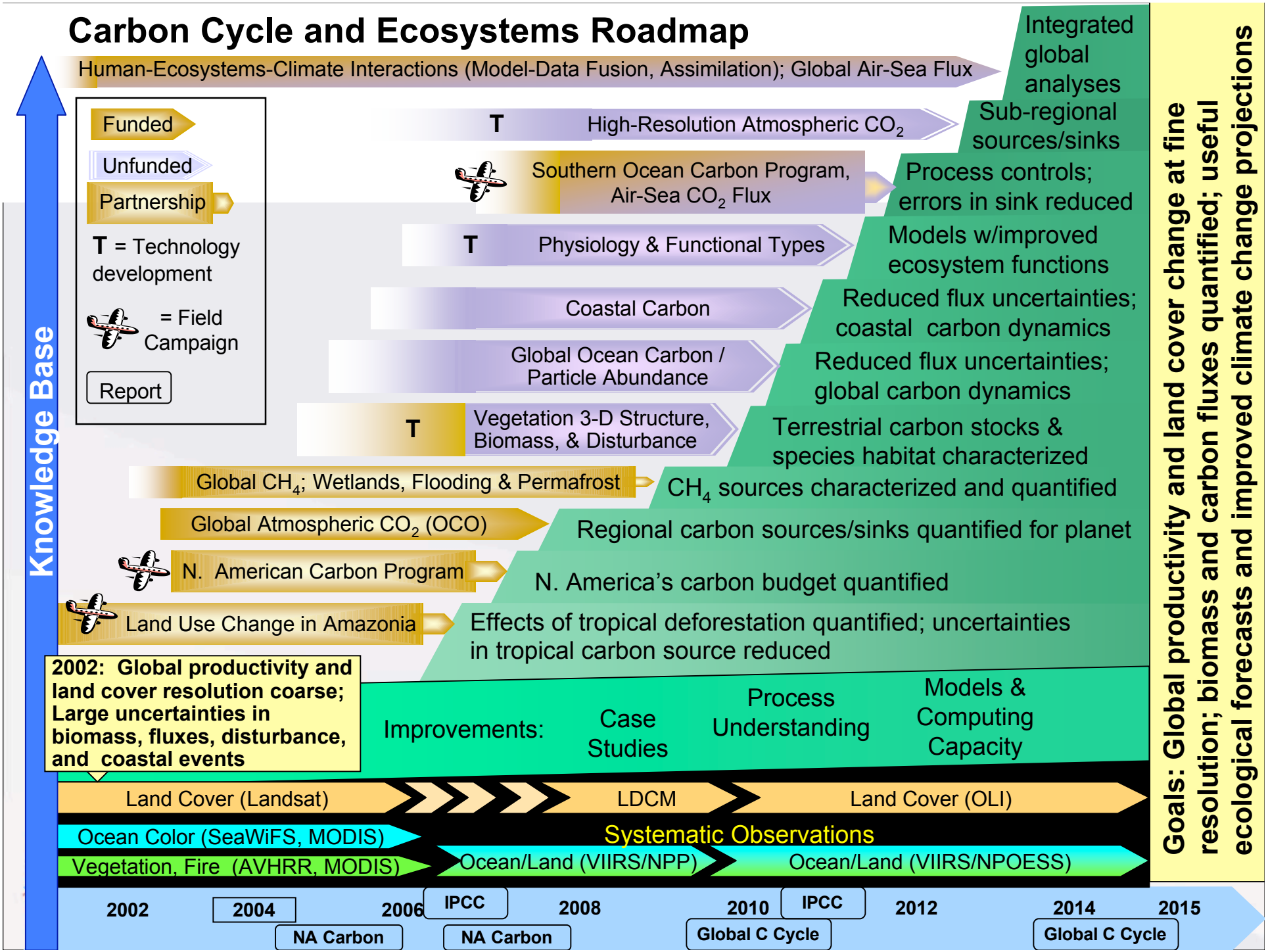
Carbon Cycle & Ecosystems Science Questions	Carbon Cycle & Ecosystems Scientific Outcomes	Carbon Cycle & Ecosystems New Measurements & Activities	Mission Target Date	Near-term Measurements	Far-term Measurements (2016 and Beyond)
How are global ecosystems changing?	Document Global Productivity	Measurements of Ocean Color Properties, Vegetation Properties, and Fire	Systematic Observation	**NPP (VIIRS) 2006 NPOESS (VIIRS) 2010**	NPOESS
	Document Global Land Cover Change	Land Cover & Land Cover Change	Systematic Observation	**LDCM 2009**	Land Cover (OLI)
	Quantify the North American carbon budget	North American Carbon Program (Field Campaign)	2007		
	CH_4 sources characterized and quantified	Global CH_4: Wetlands, Flooding, & Permafrost	2009	***LEO SAR or InSAR could address in part***	
	Terrestrial carbon stocks	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	Biomass
	Reduce flux uncertainties in global carbon dynamics	Global Ocean Carbon/Particle Abundance Mission	2010	**Global Ocean Carbon 2010**	
What changes are occurring in global land cover and land use, and what are their causes?	Quantify the effects of tropical deforestation	Land Use Change in Amazonia (LBA Field Campaign)	2006		
	Document Global Land Cover Change	Land Cover & Land Cover Change	Systematic Observation	**LDCM 2009**	Land Cover (OLI)
	Species habitat characterized	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	
	Reduced carbon flux uncertainties and global carbon dynamics	Global Ocean Carbon / Particle Abundance	2010	**Global Ocean Carbon 2010**	
	Reduced carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon 2011**	GEO Coastal Carbon
	Models with improved ecosystem functions	Physiology & Functional Types	2011	**Physiology & Functional Types 2011**	Laser-Induced Fluorescence
	Process controls and errors in Southern Ocean sink reduced	Southern Ocean Carbon Program; Air-Sea CO_2 Flux	2012		
	Sub-regional carbon sources and sinks	High-Resolution CO_2	2013	**High-Resolution CO_2 2012**	High-Resolution CO_2
What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?	Reduced carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon Mission 2011**	GEO Coastal Carbon
	Integrated global analyses of consequences	Global Models with Human-Ecosystems-Climate Interactions	2013		
What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?	Reduce flux uncertainties in coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon Mission 2011**	GEO Coastal Carbon
	Integrated global analyses of consequences	Global Models with Human-Ecosystems-Climate Interactions	2013		
How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?	Regional carbon sources/sinks quantified for planet	Global Atmospheric CO_2 (OCO)	2008	**OCO 2008**	High Resolution CO_2
	Sub-regional carbon sources/sinks quantified for planet	High Resolution Atmospheric CO2	2012	**High Resolution CO_2 2012**	High Resolution CO_2
	Models with improved ecosystem functions	Physiology and Functional Types	2011	**Physiology & Functional Types 2011**	Laser-Induced Fluorescence
	Process controls and reduced errors in Southern Ocean carbon sink	Southern Ocean Carbon Program (Field Campaign)	2012		
	Integrated global analyses	Human-Ecosystem-Climate Interactions (Model-Data Fusion, Assimilation); Global Air-Sea Flux	2013		

… *the measurement scenarios may be summarized as a* ***list of measurement/mission options****…*





… *and a "****quad chart****" of summary information prepared for each measurement/mission option…*


Carbon Cycle and Ecosystems Roadmap
Knowledge Base
Human-Ecosystems-Climate Interactions (Model-Data Fusion, Assimilation); Global Air-Sea Flux
Integrated global analyses
Funded
Unfunded
Partnership
T = Technology development
= Field Campaign
Report
T
High-Resolution Atmospheric CO2
Sub-regional sources/sinks
Southern Ocean Carbon Program, Air-Sea CO2 Flux
Process controls; errors in sink reduced
T
Physiology & Functional Types
Models w/improved ecosystem functions
Coastal Carbon
Reduced flux uncertainties; coastal carbon dynamics
Global Ocean Carbon / Particle Abundance
Reduced flux uncertainties; global carbon dynamics
T
Vegetation 3-D Structure, Biomass, & Disturbance
Terrestrial carbon stocks & species habitat characterized
Global CH4; Wetlands, Flooding & Permafrost
CH4 sources characterized and quantified
Global Atmospheric CO2 (OCO)
Regional carbon sources/sinks quantified for planet
N. American Carbon Program
N. America's carbon budget quantified
Land Use Change in Amazonia
Effects of tropical deforestation quantified; uncertainties in tropical carbon source reduced
2002: Global productivity and land cover resolution coarse; Large uncertainties in biomass, fluxes, disturbance, and coastal events
Improvements:
Case Studies
Process Understanding
Models & Computing Capacity
Land Cover (Landsat)
LDCM
Land Cover (OLI)
Ocean Color (SeaWiFS, MODIS)
Systematic Observations
Vegetation, Fire (AVHRR, MODIS)
Ocean/Land (VIIRS/NPP)
Ocean/Land (VIIRS/NPOESS)
2002
2004
2006
IPCC
2008
2010
IPCC
2012
2014
2015
NA Carbon
NA Carbon
Global C Cycle
Global C Cycle
Goals: Global productivity and land cover change at fine resolution; biomass and carbon fluxes quantified; useful ecological forecasts and improved climate change projections

Carbon Cycle & Ecosystems Measurement

Carbon Cycle & Ecosystems Science Questions	Carbon Cycle & Ecosystems Scientific Outcomes	Carbon Cycle & Ecosystems New Measurements & Activities	Mission Target Date	Near-Term Measurements	Far-Term Measurements (2016 & Beyond)
How are global ecosystems changing?	Document Global Productivity	Measurements of Ocean Color Properties, Vegetation Properties, and Fire	Systematic Observations	**NPP (VIIRS) 2006 NPOESS (VIIRS) 2010**	
	Document Global Land Cover Change	Land Cover & Land Cover Change	Systematic Observations	**LDCM 2009**	Advanced Land Cover Change
	Quantify the North American carbon budget	North American Carbon Program (Field Campaign)	2007		
	CH_4 sources characterized and quantified	Global CH_4; Wetlands, Flooding, & Permafrost	2009		
	Terrestrial carbon stocks	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	Biomass
	Reduce flux uncertainties in global carbon dynamics	Global Ocean Carbon/Particle Abundance Mission	2010	**Global Ocean Carbon 2010**	Profiles of Ocean Particles
What changes are occurring in global land cover and land use, and what are their causes?	Quantify the effects of tropical deforestation	Land Use Change in Amazonia (LBA Field Campaign)	2006		
	Document Global Land Cover Change	Land Cover a& Land Cover Change	Systematic Observations	**LDCM 2009**	Advanced Land Cover Change
	Species habitat characterized	Vegetation 3-D Structure, Biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	
	Reduce carbon flux uncertainties and global carbon dynamics	Global Ocean Carbon/Particle Abundance	2010	**Global Ocean Carbon 2010**	Profiles of Ocean Particles
	Reduce carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon 2011**	GEO Coastal Carbon

Advanced Land Cover Change

Carbon Cycle & Ecosystems

Advanced Land Cover Change

Science Objective

Make continuous measurements of land cover and land usage globally

Mission Description

- One spacecraft in low Earth sun-synchronous orbit
- Determine land cover types, including wetlands
- Determine vegetation characteristics

Measurement Strategy

- Provide landscape-scale, high-resolution, 3-dimensional mapping of the Earth's surface (vegetation and surface topography)
- Measure vegetation canopy height, vertical structure and land cover change, along with topographic change detection at sub- centimeter relative vertical accuracy
- Discriminate a wide variety of vegetation types
- Characterize habitats

Technology Requirements

- Waveform digitizers with integrated real-time pulse finding logic capable of supporting pulse rates exceeding 100 kHz
- Laser transmitters capable of 75 kHz rep-rate, ~ 5 nsec pulse widths, and 0.1 mJ pulse energy with wall plug efficiency on the order of 10%
- Laser beam deflection system capable of reliably and accurately producing a true image pattern with 100% of area illuminated on the ground at 75 kHz effective sampling rates with <1 arcsec pointing stability
- Accurate s/c positioning (< 5 cm radial) from GPS and highly accurate orientation knowledge (< 1 arcsec) using a combination of on-board star trackers and post-processed calibration
- ~300 W instrument average power during mapping phase, less during targeting phase.
- Mechanically and thermally stable optical bench mounted to platform
- Platform should be capable of 0-10 degree targeting
- This instrument will produce very high data rates

Carbon Cycle & Ecosystems Measurement (cont'd)

Carbon Cycle & Ecosystems Science Questions	Carbon Cycle & Ecosystems Scientific Outcomes	Carbon Cycle & Ecosystems New Measurements & Activities	Mission Target Date	Near-Term Measurements	Far-Term Measurements (2016 & Beyond
What changes are occurring in global land cover and land use, and what are their causes?	Models with improved ecosystems functions	Physiology & Functional Types	2011	**Physiology & Functional Types 2011**	Photosynthetic Efficiency
	Process controls and errors in Southern Ocean sink reduced	Southern Ocean Carbon Program; Air-Sea CO2 Flux	2012		
	Sub-regional carbon sources and sinks	High-Resolution CO2	2013		High Resolution CO_2
What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?	Reduced carbon flux uncertainties and coastal carbon dynamics	Coastal Carbon Mission	2011	**Coastal Carbon 2011**	GEO Coastal Carbon
	Integrated global analyses of consequences	Global Models with Human-Ecosystems-Climate Interactions	2013		
How do ecosystems, land cover, and biogeochemical cycles respond to and affect global environmental change?	Reduce uncertainties in tropical carbon source	Land Use Change in Amazonia Field Campaign	2006		
	Quantify North America's carbon budget	North American Carbon Program (Field Campaign)	2007		
	Quantify regional carbon sources/sinks on Earth	Orbiting Carbon Observatory Mission	2008	**OCO 2008**	High Resolution CO_2
	Species habitat Characterized	Vegetation 3-D Structure, biomass, & Disturbance	2010	**Vegetation Vertical Structure 2010**	Advanced Land Cover Change

Photosynthetic Efficiency

Carbon Cycle & Ecosystems

Photosynthetic Efficiency

Science Objective

Quantify marine and terrestrial productivity and efficiency of the photosynthetic process

Mission Description

- Low earth orbit satellite
- Measure induced-fluorescence of compounds diagnostic of plant health to assess quantum efficiency of photosynthesis and environmental stress.
- Measure fluorescence from chlorophyll in a band centered on ~685 nm
- Measure fluorescence from phycoerythrin (found in marine phytoplankton) in the spectral region from 450-500 nm.
- Measure induced-fluorescence of chromophoric dissolved organic matter(CDOM) across a broad region of the blue-green spectrum.

Measurement Strategy

•Measure induced-fluorescence from terrestrial or ocean plant life

Technology Requirements

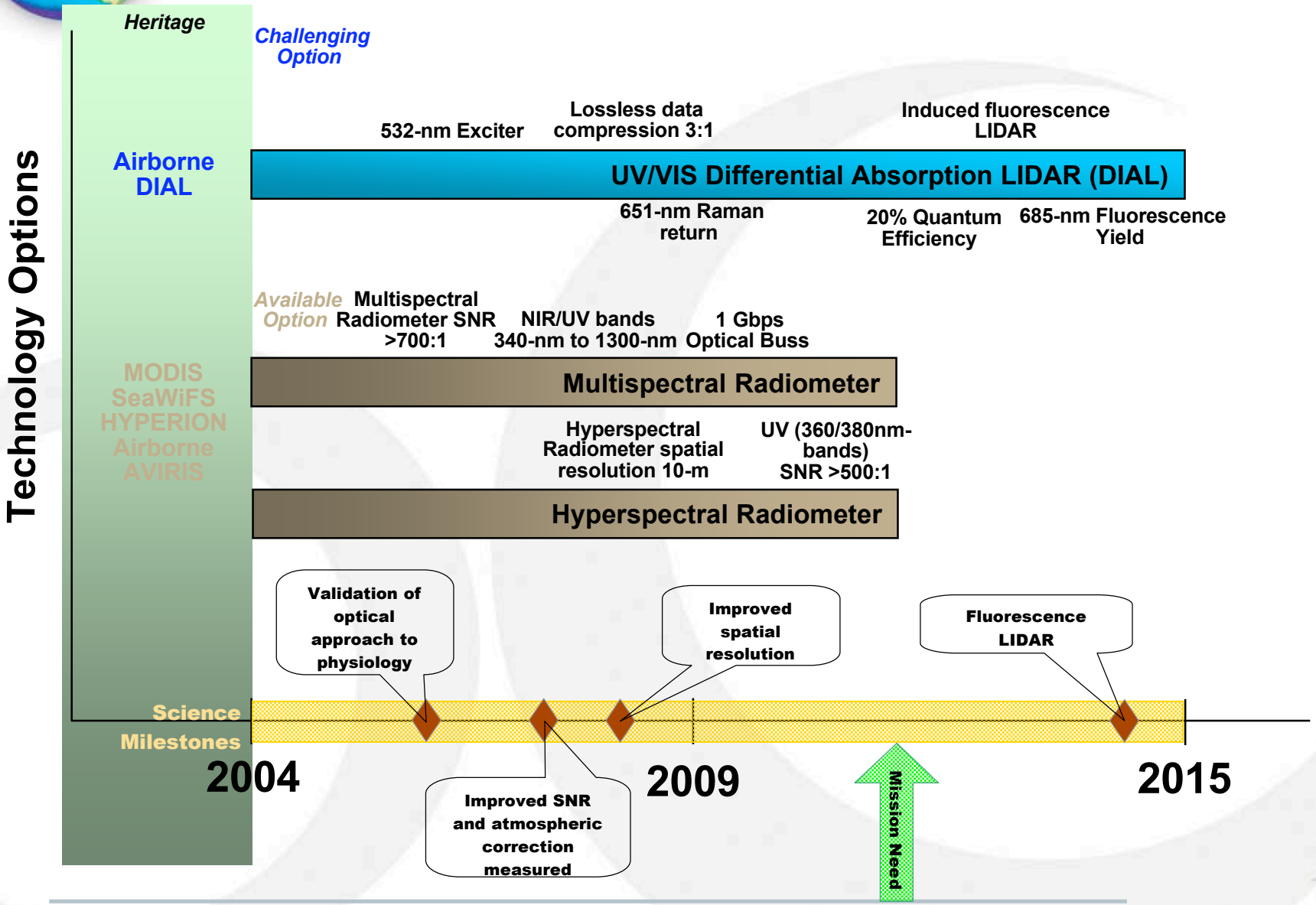
•Compact, efficient, joule-class, solid state Nd:YAG laser transmitters
•Associated harmonic generators
•High efficiency solar and elastic-scattered radiation rejection filters (>95% transmission with 1-nm bandpass)
•Meter-class lightweight optics
•Multilinear diode arrays coupled to image intensifiers

Carbon Cycle & Ecosystems

Science Measurement	Technology Options	Challenges
High Resolution Atmospheric CO_2	Profiling DIAL	1.6-um tunable fiber laser
	Lagrange Solar Occultation Spectrometer	8-m Fizeau Interferometer
	IR Laser Absorption Spectrometer	2-um, 3-W CW, rare earth solid state laser
Physiology & Functional Types	UV/VIS DIAL	>95% transmission, 1-nm bandpass rejection filters
	Multi/Hyper Radiometers	UV/NIR bands <340-1300-nm
Vegetation 3-D Structure, Biomass, & Disturbance	Imaging LIDAR	532-nm laser altimeter
	L-Band/P-Band SAR	100-m P-band transmitter/receiver

Rev 11/5/2004

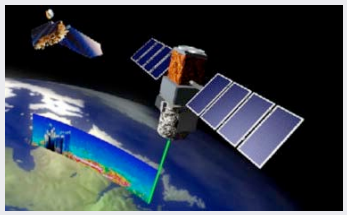
Physiology & Functional Types



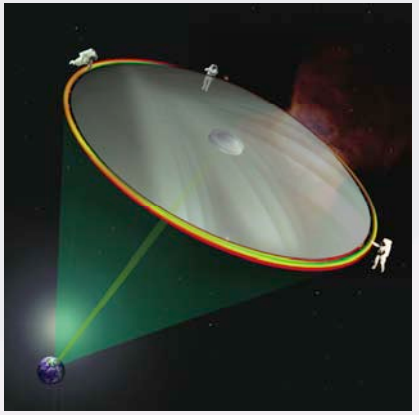
Rev 8/11/2004

ES Technology Priorities

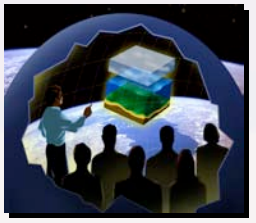
- **Active Remote Sensing Technologies** to enable atmospheric, cryospheric and earth surface measurements



- **Large Deployables** to enable future weather/climate/ natural hazards measurements



- **Intelligent Distributed Systems** using advanced communication, on-board reprogrammable processors, autonomous network control, data compression, high density storage



- **Information Knowledge Capture** through 3-D visualization, holographic memory and seamlessly linked models.

Conclusion

- **We have developed initial list of science measurements from the six focus areas**
- **We have identified measurement scenarios and technology options**
- **We have targeted technology thrust areas for investments**

Technology Enables our Future